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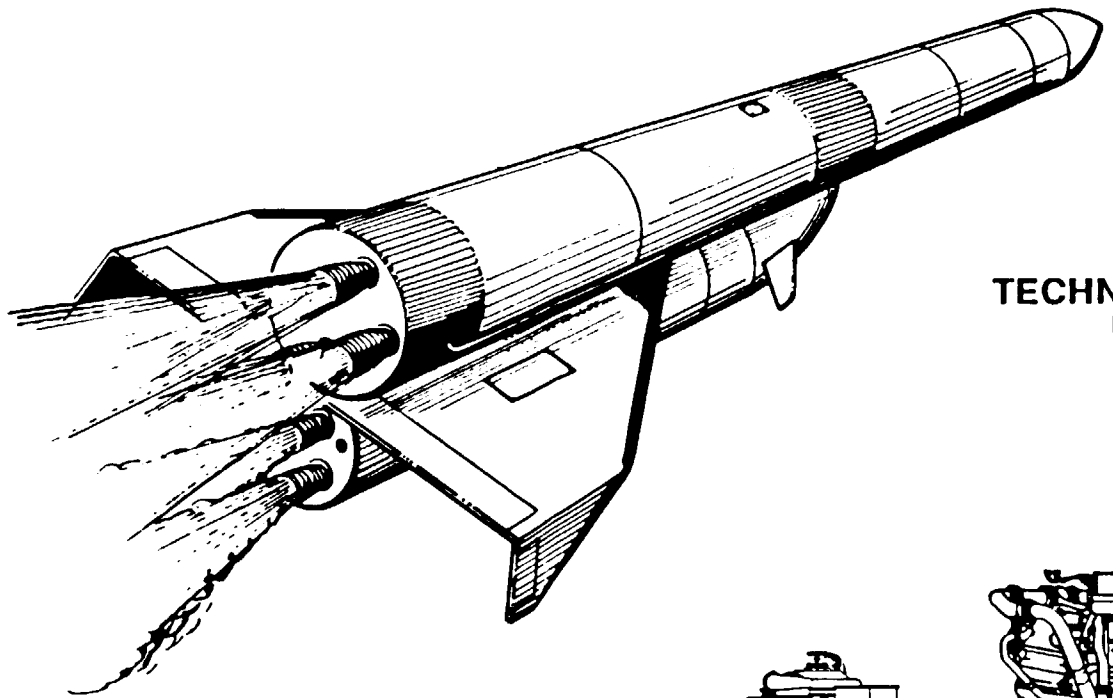
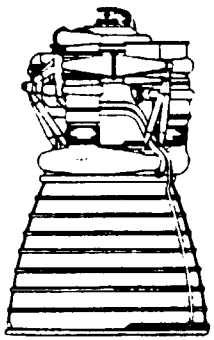
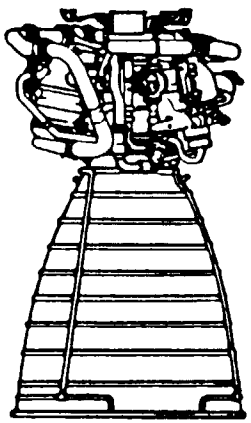
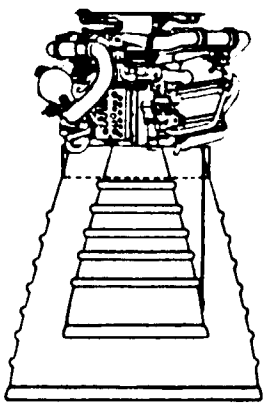
NASA
EARTH-TO-ORBIT PROPULSION R&T



TECHNOLOGY FOR FUTURE NASA MISSIONS







R.J. Richmond
NASA/MSFC
Sept. 13, 1988

PURPOSE:

- o PROVIDE A VALIDATED TECHNOLOGY BASE TO SUPPORT A RANGE OF PROPULSION SYSTEM OPTIONS FOR MINIMUM LIFE CYCLE COST FUTURE SPACE TRANSPORTATION SYSTEMS
- o MAINTAIN AND ENHANCE U.S. LEADERSHIP IN SPACE TRANSPORTATION

IMPLEMENTATION:

- o EARTH-TO-ORBIT PROPULSION R&T IS COMPOSED OF THREE PROGRAM ELEMENTS

R &T BASE PROGRAM

- Fundamental Processes
- New Concepts
- Far Term

CSTI

- o EARTH-TO-ORBIT PROPULSION
  - Oxygen/Hydrogen
  - Oxygen/Hydrocarbon
- o BOOSTER TECHNOLOGY
  - Pressure-Fed Liquids
  - Hybrids

BASE R&T PROGRAM

OBJECTIVE:

- o EXPAND FUNDAMENTAL KNOWLEDGE AND UNDERSTANDING OF ROCKET ENGINE PROCESSES AND PRINCIPLES
- o EXPLORE AND DEFINE ADVANCED TECHNOLOGIES APPLICABLE TO EARTH-TO-ORBIT PROPULSION

JUSTIFICATION:

- o APPLICATION OF NEW CONCEPTS AND IMPROVED UNDERSTANDING OF THE FUNDAMENTALS HOLDS THE POTENTIAL FOR MAJOR ADVANCEMENTS IN ETO PROPULSION

SIGNIFICANCE:

- o WILL ENABLE THE DEVELOPMENT OF FUTURE LAUNCH VEHICLES WITH FAR GREATER PAYLOAD DELIVERY CAPABILITY AT GREATLY REDUCED COST

BASE R&T PROGRAM

PROGRAM CONTENT:

- FUNDAMENTALS OF COMBUSTION AND FLUID FLOW PROCESSES
- VERY HIGH MIXTURE RATIO COMBUSTORS
- METALLIZED GELLED PROPELLANTS
- APPLICATIONS OF SUPERCONDUCTIVITY

CSTI EARTH-TO-ORBIT

OBJECTIVE:

o PROVIDE AN EXPANDED VALIDATED TECHNOLOGY BASE FOR ADVANCED OXYGEN/HYDROGEN AND OXYGEN HYDROCARBON ETO PROPULSION SYSTEMS

JUSTIFICATION:

o INCREASED BENEFITS TO SPACE TRANSPORTATION SYSTEMS THROUGH ADVANCEMENTS IN ETO PROPULSION SYSTEMS

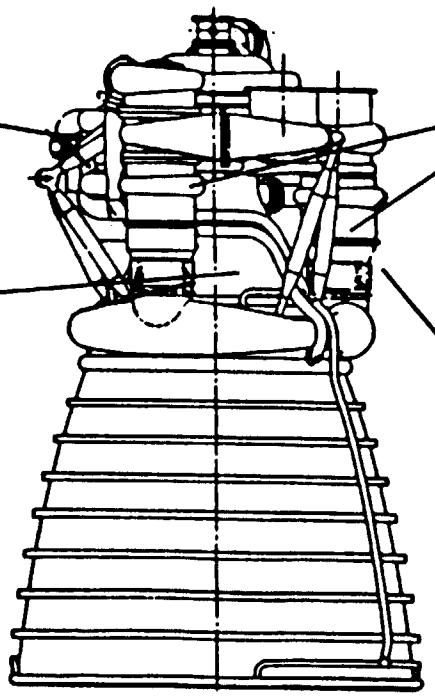
- PERFORMANCE
- SERVICE LIFE
- AUTOMATED OPERATIONS AND DIAGNOSTICS

SIGNIFICANCE:

o WILL ENABLE A RANGE OF PROPULSION SYSTEM OPTIONS FOR MINIMIZING OVERALL SPACE TRANSPORTATION COSTS

NASA CSTI EARTH-TO-ORBIT PROPULSION R&T PROGRAM

TECHNOLOGY THRUSTS



PREBURNER/GAS GEN

- UNIFORM TEMPERATURE TURBINE DRIVE GAS
- CARBON DEPOSITION

THRUST CHAMBER

- COMBUSTION EFFICIENCY
- COMBUSTION STABILITY
- PERFORMANCE PREDICTION
- CARBON DEPOSITION
- THERMAL BARRIER COATINGS
- FUEL COKING
- FUEL COOLANT/CHAMBER LINER COMPATIBILITY
- LOX COOLING
- COOLING PASSAGE GEOMETRY OPTIMIZATION
- TRANSLATING NOZZLE

TURBOMACHINERY

- BEARING DURABILITY
- ROTOR DYNAMICS
- AEROTHERMO LOADS
- COOLED TURBINES
- TURBINE BLADE DURABILITY
- HYDROGEN EMBRITTLEMENT
- TURBINE & PUMP SECTION EFFICIENCY

CONTROLS & SYSTEM MONITORING

- ADVANCED SENSORS
- DIAGNOSTIC TECHNIQUES
- CONTROL STRATEGY

CSTI EARTH-TO-ORBIT
Program Content

o ANALYTICAL/EMPIRICAL MODELS

PERFORMANCE AND LIFE PREDICTION

- Flow Process Codes
- Combustion Codes
- Heat Transfer and Cooling
- Loads Definition
- Materials Behavior
- Structural Response
- Fatigue and Fracture

o ADVANCED COMPONENT TECHNOLOGY

METHODOLOGIES AND PROCESSES

- Bearings
- Seals
- Turbine Blades
- Active Dampers
- Materials
- Coatings
- Manufacturing

CSTI EARTH-TO-ORBIT
Program Content (Cont'd)

o INSTRUMENTATION	SYSTEM MONITORING AND CONTROL - Performance Analysis - Engine Control - Safety Monitoring - Condition Monitoring
o ENGINEERING TESTING	SUBCOMPONENT VALIDATION - Models and Codes - Materials - Processes - Instruments
o SUBSYSTEM/TESTBED ENGINE TESTING	TRUE ROCKET OPERATING ENVIRONMENT VERIFCATION - Steady State - Transient - All Influences and Interactions Present

CSTI EARTH-TO-ORBIT
MAJOR DELIVERABLES

o VALIDATED ANALYTICAL CODES:

- Enhanced Structural Dynamics Codes for Internal Force Definition
- Enhanced Life Prediction Codes Based on Fracture, Fatigue
- Enhanced Rotordynamics Codes
- Enhanced Engine Performance Prediction/Combustion Codes

o ADVANCED DESIGN METHODOLOGY FOR:

- High Efficiency, Long Life Turbines, Pumps, Bearings, and Ducts
- Combustor Stability and Cooling
- Turbomachinery Stability
- Safety Monitoring, Condition Monitoring, and Control Systems

CSTI BOOSTER PROPUSLION

OBJECTIVE:

o DEVELOP THE VALIDATED DATA BASE AND DESIGN METHODOLOGY FOR ADVANCED BOOSTER PROPULSION SYSTEMS

- HIGH THRUST
- OXYGEN/HYDROCARBON PRESSURE-FED LIQUIDS
- OXYGEN/SOLID FUEL HYBRIDS

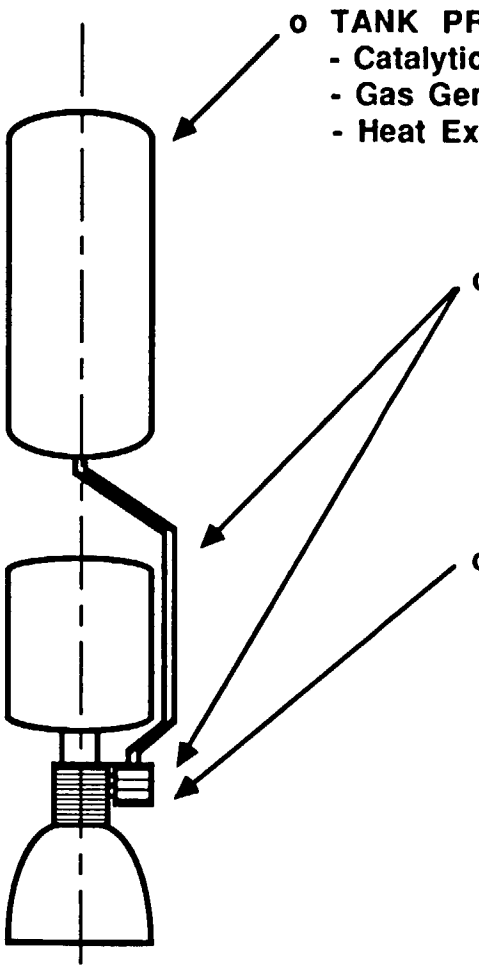
JUSTIFICATION:

o PRESSURE-FED AND HYBRID PROPULSION HAVE INCREASED PERFORMANCE, THRUST TERMINATION, AND THRUST TAILORING CHARACTERISTICS

SIGNIFICANCE:

o WILL ENABLE ALTERNATIVE OPTIONS TO THE SOLID ROCKET BOOSTERS FOR FUTURE SPACE SHUTTLE AND OTHER LAUNCH VEHICLE APPLICATIONS THAT OFFER SAFE-ABORT AND INCREASED PAYLOAD CAPABILITY

PRESSURE-FED LIQUIDS - TECHNOLOGY ISSUES

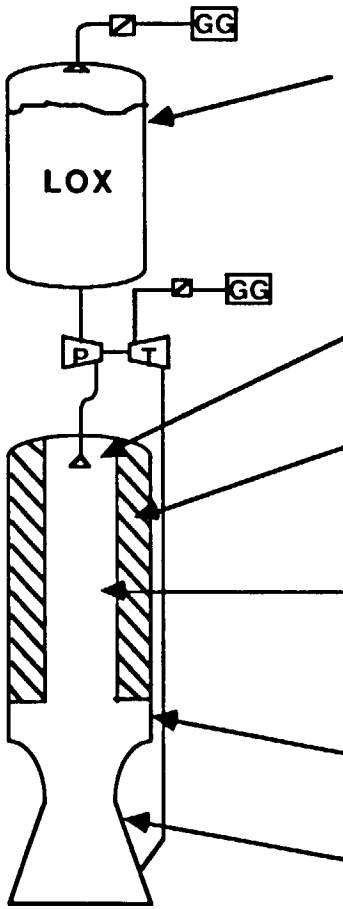


- o TANK PRESSURIZATION SYSTEMS
  - Catalytic
  - Gas Generator
  - Heat Exchanger
- o COMBUSTION PERFORMANCE & STABILITY
  - High Frequency "Acoustic" Stability
  - Low Frequency "Chugging" Modal Definition
  - Combustion Efficiency
- o THRUST CHAMBER
  - Cooling
  - Water Impact/Corrosion
  - Refurbishment

CSTI BOOSTER PROPULSION
PROGRAM CONTENT

- **PRESSURE-FED LIQUIDS**
  - ANALYTICAL MODELS
    - Low Pressure, Large Scale Combustors
    - Tank Pressurization
  - LABORATORY, SMALL SCALE TESTING FOR CODE VALIDATION
  - LARGE SCALE COMPONENT TESTING FOR DESIGN METHODOLOGY VERIFICATION
- **HYBRIDS**
  - ANALYTICAL MODELS
    - Combustion Processes
    - Propellant Feed System
  - LABORATORY, SMALL SCALE TESTING FOR CODE VALIDATION
  - SUBSCALE MOTOR TESTING FOR DESIGN METHODOLOGY VERIFICATION

HYBRIDS - TECHNOLOGY ISSUES



- o OXIDIZER FEED SYSTEM
  - Tank Pressurization Gas Generator
  - Turbomachinery
  - Turbine Drive Gas Generator
- o IGNITION SYSTEM OPTIMIZATION
- o FUEL GRAIN ASSESSMENT
  - Composition, Producibility
  - Burning Rate Characteristics
  - Mechanical Properties
- o INTERNAL BALLISTICS
  - Propellant Tailoring
  - Oxidizer Injection
  - Combustion Process Optimization
- o INSULATION MATERIALS CHARACTERIZATION
- o NOZZLE DESIGN AND FABRICATION

CSTI BOOSTER PROPULSION
MAJOR DELIVERABLES

o VALIDATED ANALYTICAL CODES:

- Low to Moderate Pressure, Bipropellant Combustion Processes
- Hybrid Combustion Processes
- High and Low Mixture Ratio Combustion for Tank Pressurization
- In-Tank Condensible Predictions

o ADVANCED DESIGN METHODOLOGY FOR:

- Pressure-Fed Combustor Design with High Performance, Stable Combustion, Minimum Pressure Drop Cooling, and Minimum Weight Ablative
- Hybrid Solid Fuel Grain Design, Oxidizer Injection and Ignition Systems
- High and Low Mixture Ratio Combustors
- High and Low Mixture Ratio Ignition Systems